APPARATUS AND METHOD FOR TREATING POLLUTANTS IN A GAS USING HYDROGEN PEROXIDE AND UV LIGHT

Origin of Invention

The invention described herein was made in the performance of work under a NASA contract and by an employee of the United States Government and is subject to the provisions of Public Law 96-517 (35 U.S.C. §202) and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefore. In accordance with 35 U.S.C. §202, the contractor elected not to retain title.

Related Application

This application is based upon co-pending provisional application Serial No. 60/267,401 filed February 7, 2001, the entire contents of which are incorporated herein by reference.

Field of the Invention

The present invention relates generally to the field of pollution control, and, more particularly, to reducing air pollutants in gases.

Background of the Invention

NOx and other air pollutants, such as CO and VOCs, are often found in combustion flue gasses.

Selective catalytic reduction (SCR) is often used to control NOx. In particular, cheaper and more effective technology is desired to control NOx emissions from large combustion sources (power plants, large boilers, etc.).

There has been research over the past decade on using hydrogen peroxide to oxidize NOx in flue gas to more scrubbable species. The hydrogen peroxide is injected into hot flue gas and thermally splits to form very active free radicals that attack the NOx so that downstream scrubbing can remove the species created. Unfortunately, this activation of hydrogen peroxide does not readily occur at low temperatures by itself. Thus, there is a desire for technology that may also be effective even at relatively low-temperatures.

Attempts have been made to remove air pollutants from flue gasses, and, in some cases, at relatively low temperatures. For example, U.S. Patent No. 5,670,122 to Zamansky et al. discloses a method for removing air pollutants from combustion flue gases. The method comprises adding hydrogen peroxide and/or methanol to a combustion flue gas that is between 377°C and 827°C. The hydrogen peroxide and/or methanol react with the air pollutants in the flue gas and remove nitric oxide, sulfur trioxide, light hydrocarbons, carbon monoxide, and trace amounts of mercury from the combustion flue gas.

Other technologies use ultraviolet light to dissociate hydrogen peroxide for greater performance. For example, one approach places the UV light in the gas flow tube which carries the flue gas. Alternately, the UV light is delivered by a UV lamp in a large (dilute) liquid container within a separate reactor vessel. Prior research and practice used ordinary injection nozzles for the hydrogen peroxide that were separate from the UV light source.

Attempts have been made to improve the efficiency of removing air pollutants when using

hydrogen peroxide and UV light. For example, U.S. Patent No. 5,256,379 to Deloach discloses an apparatus for removing hydrocarbon contaminants from an air stream that flows through a chamber. UV light passes through the chamber and irradiates the hydrogen peroxide. The UV light source is located outside the chamber that the hydrogen peroxide passes through. The effect is that the hydrogen peroxide does not efficiently absorb all of the UV light because not all of the UV light passes through the chamber.

Moreover, prior technology is often limited because there are competing reactions involving the UV light, it is difficult to keep the UV lamps cooled, and there is a possibility of UV leakage out of the reactor. Thus, there is a need for technology that more efficiently irradiates hydrogen peroxide to be subsequently used for removing air pollutants from gases, such as flue gasses from stationary sources.

Summary of the Invention

In view of the foregoing background, it is therefore an object of the invention to provide a method and apparatus for efficiently creating and injecting dissociated hydrogen peroxide into gases, such as flue gases, to thereby treat pollutants, such as NOx, for example.

This and other objects, features and advantages in accordance with the present invention are provided by an apparatus for treating pollutants in a gas that includes at least one UV lamp within a treatment injector housing through which the hydrogen peroxide passes. More particularly, the overall treatment apparatus may include a gas flow tube that carries a flow of gas, such as flue gas. The treatment injector cooperates with a source of hydrogen peroxide for creating and injecting dissociated hydrogen peroxide into the flow of gas. By activating the hydrogen peroxide with UV light and efficiently

delivering the activated hydrogen peroxide to the gas, greater pollutant treatment efficiency may be obtained, especially at lower temperatures.

The treatment injector may further comprise an injector housing having an inlet, an outlet, and a hollow interior extending between the inlet and outlet. The inlet may be connected in fluid communication with the source of hydrogen peroxide so that hydrogen peroxide flows through the hollow interior and toward the outlet.

At least one UV lamp may be positioned within the hollow interior of the injector housing. The UV lamp may dissociate the hydrogen peroxide flowing through the injector housing. The dissociated hydrogen peroxide may be injected into the flow of gas from the outlet for treating pollutants in the flow of gas. For example, the apparatus may be for reducing nitrogen oxides in flue gas from a stationary source.

The apparatus may further comprise a scrubber connected to the gas flow tube downstream from the treatment injector. The scrubber may remove reaction products of the pollutants with the dissociated hydrogen peroxide.

Additionally, the apparatus may comprise an air source connected in fluid communication with the inlet of the injector housing. A heater may also be provided to heat the air, and, thus, heat the hydrogen peroxide within the injector housing.

The outlet of the treatment injector may be connected in fluid communication with an opening in the sidewall of the gas flow tube. In one class of embodiments, the injector housing may have a generally tubular shape that extends through the opening in the sidewall of the gas flow tube. The UV lamp may have an elongate shape and may be oriented generally parallel to the tubular shape of the injector housing. In another class of embodiments, the injector housing is external to the gas flow tube. The UV lamp may have an

elongate shape and may be oriented transverse to the tubular shape of the injector housing.

The treatment injector may comprise a UV reflective coating on the interior of the injector housing. Boric acid may be used as a coating applied on the interior of the injector housing to reduce or prevent undesired decomposition of the hydrogen peroxide on the walls of the injector housing. A cooling fan may also be associated with the UV lamp.

Another aspect of the invention relates to a method for treating pollutants in a flow of gas carried by a gas flow tube and using a hydrogen peroxide source. More particularly, the method may comprise coupling a treatment injector between the hydrogen peroxide source and the gas flow tube. The treatment injector may comprise an injector housing having an inlet, an outlet and a hollow interior extending therebetween. The inlet may be connected in fluid communication with the source of hydrogen peroxide. The treatment injector may further comprise at least one UV lamp positioned within the hollow interior of the injector housing.

Furthermore, the method may include flowing hydrogen peroxide through the hollow interior of the injector housing and toward the outlet while operating the at least one UV lamp to dissociate the hydrogen peroxide. Accordingly, the dissociated hydrogen peroxide is injected into the flow of gas from the outlet for treating the pollutants.

Brief Description of the Drawings

FIG. 1 is a schematic diagram of a first embodiment of the apparatus in accordance with the invention.

FIG. 2 is a schematic diagram of a second embodiment of the apparatus in accordance with the invention.

FIG. 3 is a flow chart illustrating a method

in accordance with the invention.

Detailed Description of the Preferred Embodiments

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. However, this invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

Referring to FIG. 1, a first embodiment of the apparatus **10** for treating a gas including pollutants is now described. In the illustrated embodiment, the apparatus **10** includes a gas flow tube **11** having a sidewall opening **27** therein. The gas flow tube **11** carries a flow of gas illustrated by the arrows labeled **26**. For example, the gas **26** may be a flue gas from a stationary source **21**, such as a power plant, industrial boiler, or other similar source as will be appreciated by those skilled in the art. Of course, in other embodiments, the source may be mobile rather than stationary.

The apparatus **10** also includes a source of hydrogen peroxide **19**. For example, the hydrogen peroxide source **19** may deliver the hydrogen peroxide as a mist or liquid as will be appreciated by those skilled in the art. A treatment injector **13** is connected to and cooperates with the source of hydrogen peroxide **19** for injecting radicals formed by the dissociation of the hydrogen peroxide and indicated by arrows labeled **28** into the flow of gas **26**.

The treatment injector **13**, in turn, illustratively includes an injector housing **15** having one or more inlets **16**, an outlet **29**, and a hollow

interior **30** extending therebetween. The inlet **16** may be connected in fluid communication with the source of hydrogen peroxide **19** so that hydrogen peroxide flows through the hollow interior **30** of the injector housing **15** and toward the injector housing outlet **29**. In other words, the hydrogen peroxide is at a higher pressure than the pressure of the flue gas **26** and therefore flows through the hollow interior **30** of the injector housing **15**.

A UV lamp **18** is illustratively positioned within the hollow interior **30** of the injector housing **15**. The UV lamp **18** is connected to the electrical power source **12** and provides UV radiation which dissociates the hydrogen peroxide flowing through the injector housing **15** to generate the radicals to thereby treat one or more pollutants in the flue gas **26** as will be appreciated by those skilled in the art. One advantage of positioning the UV lamp **18** within the hollow interior **30** of the injector housing **15** is that the flow of hydrogen peroxide also provides cooling for the lamp.

The dissociated hydrogen peroxide **28** may be discharged from the outlet **29** and into the flow of gas **26**, such as for converting nitrogen oxides into compounds which can be readily removed by the downstream scrubber **17**, for example. Other pollutants that may be similarly treated include, without limitation, CO and various VOCs, for example. Further details regarding the chemistry for removal of nitrogen oxides, for example, such as emitted from a stationary source **21** and using hydrogen peroxide radicals will be appreciated by those skilled in the art. A further discussion may be found in copending U.S. patent application serial no. 09/698,607, entitled ?Air Pollution Control Method and Apparatus For Removal of Nitrogen Oxides From Station Combustion Sources, filed on October 27, 2000, and assigned to the assignee of the present invention. The entire contents of this

patent application are incorporated herein by reference.

The apparatus **10** also illustratively includes an air source **20**, connected in fluid communication with the inlet **16** of the injector housing **15**. The air source **20** may be optionally used to provide the desired positive pressure to cause the flow of dissociated hydrogen peroxide **28** from the outlet **29** as will be appreciated by those skilled in the art. Of course the air flow may also provide cooling for the UV lamp **18**.

In the illustrated embodiment, the injector housing **15** is positioned to extend into the sidewall opening **27** of the gas flow tube **11**. The injector housing **15**, may have a generally tubular shape, for example, although other shapes are also contemplated by the invention. The UV **18** lamp also illustratively has an elongate shape and is oriented generally parallel to the tubular shape of the injector housing **15**. Other similar UV lamp **18** orientations known to one of ordinary skill in the art are also possible. In addition, multiple such lamps **18** may be positioned within the hollow interior **30** of the injector housing **15** as will be described in greater detail below.

The injector housing **15** may comprise metal or a ceramic material, for example. In addition, at least one coating **14** may be provided on the interior of the injector housing **15**. The coating **14** may be a UV reflective material, for example. The coating **14** may alternately comprise boric acid to help prevent undesired decomposition of the hydrogen peroxide. Of course, other materials may also be used as a coating **14** with similar advantageous properties to boric acid, for example, as will be appreciated by those skilled in the art.

Turning now additionally to FIG. 2, a second embodiment of the apparatus **30** in accordance with the invention is now described. In this embodiment, the treatment injector **34** and its housing **38** are completely

external to the gas flow tube **48** which carries the flow of gas **43** from the source **46**.

The injector housing includes an inlet **50**, an outlet **51** and a hollow interior **53** extending therebetween as in the above described embodiment. The outlet **51** is coupled to the flow of gas **43** from the source **46** and through the gas flow tube **48**.

In this embodiment, however, a pair of UV lamp assemblies **54a, 54b** are positioned in spaced apart relation and extend transverse to the hollow interior **53** and, thus, transverse to the flow of hydrogen peroxide through the interior. Each UV lamp assembly **54a, 54b** illustratively includes a respective UV lamp **55a, 55b** surrounded by a respective quartz or UV transparent housing **56a, 56b**. Each UV lamp assembly **54a, 54b** also illustratively includes a respective optional air blower **57a, 57b** for delivering a flow of cooling air into the space between the housing and lamp. The UV lamp assemblies **54a, 54b** create dissociated hydrogen peroxide **58** which exits through the outlet **51** and into the flow of gas **43** being treated.

The inlet **50** is coupled to a chamber **35** which, in turn, is connected to the hydrogen peroxide source **45**. An air source **37** is also coupled to the chamber **35** so that a flow of air can be controllably added to the flow of hydrogen peroxide. In addition, a heater **58** is illustratively provided in the chamber **35** to thereby heat the air, and, thus, heat the hydrogen peroxide as will be appreciated by those of skill in the art. The heater **38** is connected to an electric power source **36**, as are the UV lamp assemblies **54a, 54b** and blowers **57a, 57b**. The heater **38** is optional and may not be needed in all embodiments as will also be appreciated by those skilled in the art.

Another aspect of the invention relates to a method for reducing pollutants in a flow of gas carried by a gas flow tube using a hydrogen peroxide source. This method is more fully explained with additional reference to the flow chart **60** of FIG. 3. From the start (Block **62**), the method includes at Block **66** coupling a treatment injector **13** (FIG. 1), **34** (FIG. 2) between the hydrogen peroxide source **19, 45** and the gas flow tube **11, 48.** The treatment injector **13, 34** may comprise an injector housing **15, 38** having an inlet **16, 50**, an outlet **29, 51**, and a hollow interior **30, 53** extending therebetween. The inlet **16, 50** may be connected in fluid communication with the source of hydrogen peroxide **19, 45.** The treatment injector **13, 34** may further comprise at least one UV lamp **18, 55a, 55b** positioned within the hollow interior **13, 53** of the injector housing **15, 38.**

At Block **66** hydrogen peroxide is flowed through the hollow interior **30, 53** of the injector housing **15, 38** and toward the outlet **29, 51** while operating the at least one UV lamp **18, 54a, 54b** to dissociate hydrogen peroxide **28, 58.**

At Block **68** the method may also include delivering a flow of air, such as heated air, to the inlet **29, 51** of the injector housing **15, 38.** Additionally, at Block **70** the dissociated hydrogen peroxide is injected into the flow of gas. The gas so treated may be scrubbed (Block **72**) to remove reactant products formed by the dissociated hydrogen peroxide and pollutants in the flow of gas, before stopping at Block **74.**

In brief summary: the apparatus and associated method use UV light to dissociate the hydrogen peroxide, and the hydrogen peroxide is closely contained adjacent to the UV lamp, thus providing cooling for the lamp, and while pre-heating the hydrogen peroxide. Also, containing the UV light in

the treatment injector advantageously couples substantially all of the light?s energy into the hydrogen peroxide so there is less wasted UV light, such as occurs in conventional treatment approaches.

The following TABLES 1-3 show test results using a prototype apparatus including the treatment injector similar to that shown in FIG. 2 and as described above. The data is broken down based upon low, medium or high temperatures. In addition, none, one or both of the UV lamps were used to generate the data as indicated. As can be readily appreciated by those skilled in the art, the treatment injector of the present invention provides more efficient conversion particularly, for low-temperature gases.

TABLE 1- Low Temperature Data

Run	# Lamps	Temp. F	NO Conv., %	NOx Conv., %
#9	0	186	1.1	0.0
#8	0	186	1.9	0.0
#1	0	186	0.0	0.0
		averages	**1.0**	**0.0**
#6	1	186	1.5	0.0
#7	1	186	1.9	0.0
#2	1	186	2.3	0.0
		averages	**1.9**	**0.0**
#5	2	186	1.5	2.2
#4	2	186	1.9	2.2
#3	2	186	4.1	2.2
		averages	**2.5**	**2.2**

TABLE 2- Medium Temperature Data

Run	# Lamps	Temp. F	NO Conv., %	NOx Conv., %
#10	0	320	0.0	0.0
#9	0	320	0.0	0.0
#8	0	360	0.0	0.0
#9	0	360	0.0	0.0
#11	0	320	0.0	0.0
#8	0	320	0.0	0.0
#1	0	360	1.2	0.0
		averages	**0.2**	**0.0**
#1	1	320	1.7	0.0
#6	1	320	5.3	3.4
#7	1	360	6.1	2.7
#6	1	360	15.4	10.7
#12	1	320	4.8	2.3
#2	1	320	6.1	1.5
#7	1	320	5.7	0.0
#2	1	360	6.4	1.9
		averages	**6.5**	**2.8**
#5	2	320	5.9	1.6
#4	2	360	5.1	1.0
#5	2	360	11.1	5.7

#3	2	320	9.5	0.0
#4	2	320	8.0	2.8
#3	2	360	9.5	3.5
		averages	**8.2**	**2.4**

TABLE 3- High Temperature Data

Run	Lamps	Temp. F	NO Conv., %	NOx Conv., %
#5	0	580	32.2	14.1
#6	0	580	35.6	16.7
		averages	**33.9**	**15.4**
#1	1	580	32.7	15.6
#2	1	580	52.5	25.2
		averages	**42.6**	**20.4**
#4	2	580	46.4	20.4
#3	2	580	64.3	32.3
		averages	**55.4**	**26.5**

Many modifications and other embodiments of the invention will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention is not limited to the specific embodiments disclosed, and that the modifications and embodiments are intended to be included within the scope of the depending claims.